FAIRCLO

Design of a Steel Coal Tower

Civil Engineering
B. S.

1902

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DESIGN OF A STEEL COAL-TOWER

BY

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THESIS FOR DEGREE OF BACHELOR OF SCIENCE
IN CIVIL ENGINEERING

COLLEGE OF ENGINEERING
UNIVERSITY OF ILLINOIS
PRESENTED JUNE 1902

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May 31 1902

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

George Cassius Fairclo

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IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Science in Civil Engineering

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HEAD OF DEPARTMENT OF Civil Engineering

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Design of a Steel Tower for a Coal Mine.

The writer having been employed recently by the Chicago, Wilmington and Vermillion Coal Company has taken for his Thesis the Design of a Steel Tower for one of its mines at Thayer Illinois. Within the past few years the use of steel for coal towers in Illinois has been growing quite rapidly and will probably become general in all cases where the life of the mine will be twenty years or over.

While the first cost is and always has been greatly in favor of the wooden structure, the greater durability, saving in insurance and security from loss by fire; has been sufficient to cause mining companies to adopt steel construction for most of the better class of mines. The saving in insurance by making the buildings fire-

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proof is often enough to pay a good rate of interest on much more than the difference between the first cost of the wooden tower and the steel tower.

Probably the principal thought connected with the incurring of the extra expense of a steel tower is to avoid the danger of destroying the buildings in the vicinity of the opening of the mine by fire, and also the possibility of fire being transferred through the wooden lining of the shaft to the mine, thus destroying the shaft and firing the mine.

The danger from fire has been recognised by the law when it states: "Any building erected after the passage of this act, for the purpose of housing the hoisting engine or boilers at any mine shall be substantially fire-proof, and

no boiler house shall be nearer than sixty feet to the main shaft or opening or to any building or inflamable structure connected there with"; and again when it says: "It shall be unlawful to erect any inflamable structure or building in the space intervening between the main shaft and the escapement shaft on the surface, or any powder magazine, in such location or manner as to jeapordize the free and safe exit of the men from the mine, by said escapement shaft, in case of fire in the main-shaft buildings". This law was doubtless passed because of the danger to the miners resulting from the burning of the shaft buildings.

The advantage to the operator of a steel tower is very great in the security

it gives protection from fire during the months of fall and winter when coal is badly needed and is bringing a big price. This is well illustrated by Mr. A. J. Moorshead, General Manager of the Madison Coal Company when he says: "We believe that we have embodied all the best details in our steel tower at Dixmont; and we feel, of course, a great security in its possession, for it makes the plant practically fire proof. This was well illustrated to us the other day, when, on December 1st, our wooden mine tower of Number 2 at Glen Carbon burned to the ground and very nearly swept away the power houses. The same thing happened at Donk Brothers Coal and Coke

Company's mine number 1 at Cuba, Illinois: and some time prior to that the Sorento mine tower burned to the ground. Such cases usually occur at the period of the year when you can ill afford to be without your plant for a single day, because the fall and winter are the profitable seasons in coal mining. While a steel tower will cost fully twice as much as a wooden tower, yet with care in keeping it painted and free from rust, it will last as long as the mine can be profitably be operated, and you have nothing to fear from fire in the winter months, when you have an opportunity to make money. Wish all our towers were steel."

The shaft must be lined with

wood, and a slight danger from fire results; but the steel tower reduces this to a minimum. Besides, since generally throughout the state of Illinois water is found in the sand and gravel strata from twenty to fifty feet below the surface, these timbers are always wet from that point to the bottom of the shaft; and therefore there is no need to fear fire in the shaft lining. At the bottom of the shaft, light steel I beams should be used instead of heavy timbers, and thus all danger from fire is avoided at that point.

In the early construction of steel tipples in Illinois there was a tendency to "tack on" such an amount of wood as to destroy the utility of the steel

structure as a fire-proof structure, but this has been remedied in the later construction.

Outline Description.

The structure to be designed consists primarily of a tower over the shaft, which supports on its top a pair of sheave wheels carrying a hoisting cable for each compartment of the shaft. This tower is supported by a back-stay or leg to neutralize the overturning affect of the cable running to the hoisting engine. On the opposite side to the back-stay is a tower to support one end of the office and weighing platform. Between these two towers and under the dumping platform is an open space for the shaker screen.

All of the above can be seen from the north elevation of the detail plan of Plate I. The details of the general arrangement are shown by the additional drawings in Plate I and still farther by the detailed drawings in Plate II

It is proposed to compute the stresses in the several members and then determine their proper cross section. The determination of the stresses is in the main comparatively simple.

Stresses in the Tower.

The stresses in the various members of the tower will first be computed.

The Loads. The live load on the cable is:

Cage	2000 pounds
Car	2000 "
Coal	6000 " 10000 lbs.

There is a possibility that there may be a loaded cage on each cable at the same time, and therefore the load on the top of the tower may be 1000 x 2 = 20000 pounds. The weight of 350 feet of 1¼ inch steel cable is 885 pounds. It will be assumed that the tension upon one hoisting cable may be increased two fold because of the cage's binding on the guides; and therefore the maximum assumed live load upon the top of the tower will be taken as 30885 pounds.

The dead load will be the weight of the structure and the loading on the floor at the dumping line. The weight of the structure will be assumed at 20000 pounds, 16000 pounds of which will be assumed as taken by the four corner posts of the tower and

4000 pounds by the corner posts under the weighing office.

The wind load will be taken as 20 pounds per square foot on the sides of the structure, the wind pressure on the roof being neglected.

Allowable live load stress.

$12500 - 54\frac{l}{r}$, allowable dead load stress $25000 - 108\frac{l}{r}$. An increase of 30 o/o of allowable live and dead load stress will be taken as allowable stress for combined stresses. Allowable live load tension 10000 pounds, allowable dead load tension 20000 pounds.

Stresses in Posts.

The inner posts BCDGHI, Plate I, will be designated as tower posts; the posts AEFJLN will be designated as corner posts.

the posts KMO will be designated as intermediate posts

The tower posts must carry the dead load resting directly upon them, and the stresses due to the wind against the tower, and a component of the stress in the hoisting cable.

The first is so easily found as to need no comments. The second is found by the usual method for finding wind stresses in metal buildings. The third is found by a comparatively easy process, not here explained.

The corner posts take wind load, 2000 pounds dead load, and the weight on the tipple floor. The intermediate posts KM and O take dead load due to weight on tipple floor only.

The latter have no lateral bracing

and get stress due to the bending moment of the wind. When the wind is blowing from the south the load is considered as taken by posts L K and N O and the lateral bracing between them; when the wind is blowing from the east or west, the load is considered as carried by M N, and L M and the lateral bracing between them.

In order to secure uniformity in the many posts, the section of the post having the maximum stress will be taken as the section of all. The post having the greatest stress is G, Plate I

The stresses on it are:

Dead load stress.	Weight of structure	4000 pounds
	Load on floor	5565 "
	Total	9565 "

Live load stress:

A live load of 13500 pounds is taken by posts G H and I. Post I gets one fourth, equals 3375 pounds

Total 12940 pounds.

The direct compression due to wind is 52130 pounds — see Figure 1, Page There is a small stress at the foot of the column due to bending, but as the column is fixed at the bottom the lever arm would be only 0.25 feet thus making the stress so small as to be neglected.

Section of Posts. For each of the six posts B.C.D.G.H.I. Plate I we will take 1 angle 6" x 6" x $\frac{7}{16}$". Area 5.06 sq in. r = 1.19 l = 72 inches. Allowable Live Load stress = $12500 - 54\frac{72}{1.19} = 9200$ pounds. Allowable Dead Load stress = $25000 - 108\frac{72}{1.19} = 18400$

pounds. Required area for Live Load = $\frac{3375}{9200}$ = .37 sq. in. Required area for Dead Load = $\frac{9565}{18400}$ = .52 sq. in. The wind exceeds 30% of dead and live loads, and hence must be considered. Total area for dead and live loads = .37 + .52 = .89 sq. in. Allowable dead and live load stress = $\frac{3375 + 9565}{.89}$ = 14550 pounds. New allowable stress when wind is considered = 14550 + 30% = 18900 pounds. Entire stress = 3375 + 9565 + 52160 = 65070 pounds. Required area = $\frac{65070}{18900}$ = 3.45 square inches.

Section of Struts. In order to secure uniformity in the struts, the section of the bottom strut, which has the maximum stress - see Figure 1 Page will be made the section of all.

The stress on it is:

Wind load stress 21825 pounds.

For the bottom strut we will take 2 angles 3"x4"x$\frac{5}{16}$" placed $\frac{1}{4}$ inch back to back. Area 7.18 square inches r 1.25 l = 78 inches. Allowable live load stress = 12500 - 54 $\frac{78}{1.25}$ = 9150 pounds. Allowable stress when wind is considered = 9150 + 30% = 11900 pounds. Required area = $\frac{21825}{11900}$ = 1.83 square inches.

Section of Tension Web Members. In order to secure uniformity in the web members, the section of the member having the maximum tension will be made the section of all. The stress in it is 26700 pounds - see Figure 1, Page . For the bottom web member we will take 1 angle 3"x3"x$\frac{5}{16}$" Area 1.78 square inches. Allowable stress 20000 pounds. Required area $\frac{26700}{20000}$ = 1.34 square inches.

In a somewhat similar manner the sections of the posts K, L, M, N and O were designed. The sections of these posts are shown in plate I

Stresses in Back-stay.

The direct compression is 36000 pounds.

The wind stress is small and can be neglected.

The dead load stress is small and can be neglected.

Section of members.

For the posts take 2 angles $6'' \times 4'' \times \frac{3}{8}''$. Area 7.22 square inches. $l = 121$ inches. $r = 1.17$ $\frac{36000}{2} = 18000$ pounds on one post. $\frac{18000}{7.22} = 1250$ pounds direct compression. The stress due to cross bending $= f = \frac{M y}{I - \frac{P l^2}{10 E}}$ (Johnson's "Framed Structures") $M = 16575$ inch pounds $y = 6\frac{1}{8}$ inches $I = 54.15$ $P = 1250$ pounds $l^2 = 640$ $E = 28000000$ $f = \frac{16575 \times 6\frac{1}{8}}{54.15 - .0 +} = 1900$ pounds. Stress $= 1250 + 1900 = 2150$

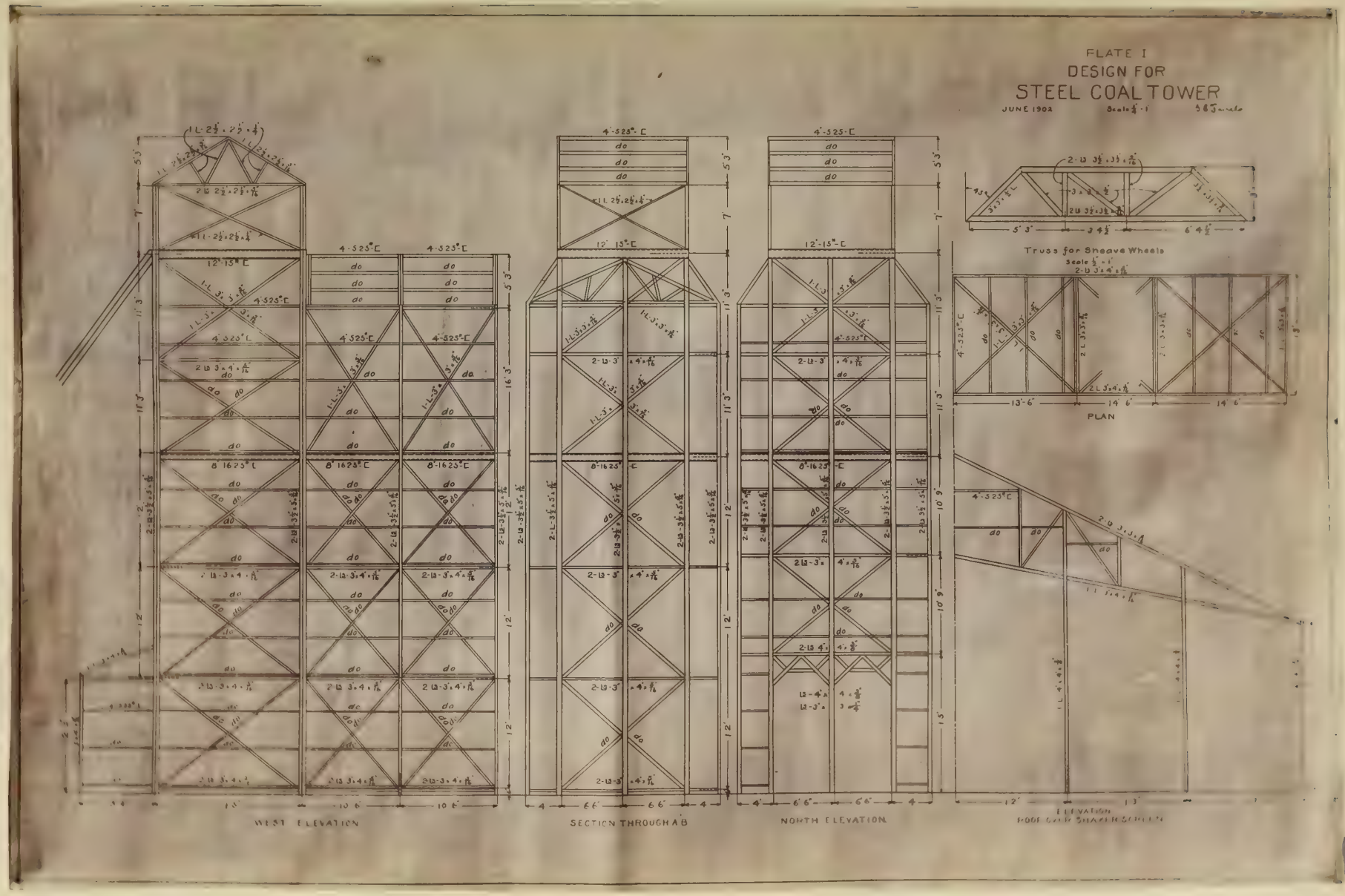
pounds. Allowable stress = $12500 - 54\frac{l}{r} =$

$12500 - 5560 = 6940$ pounds.

PLATE I

DESIGN FOR STEEL COAL TOWER

JUNE 1902 Scale ½" = 1' S. B. Jarvis



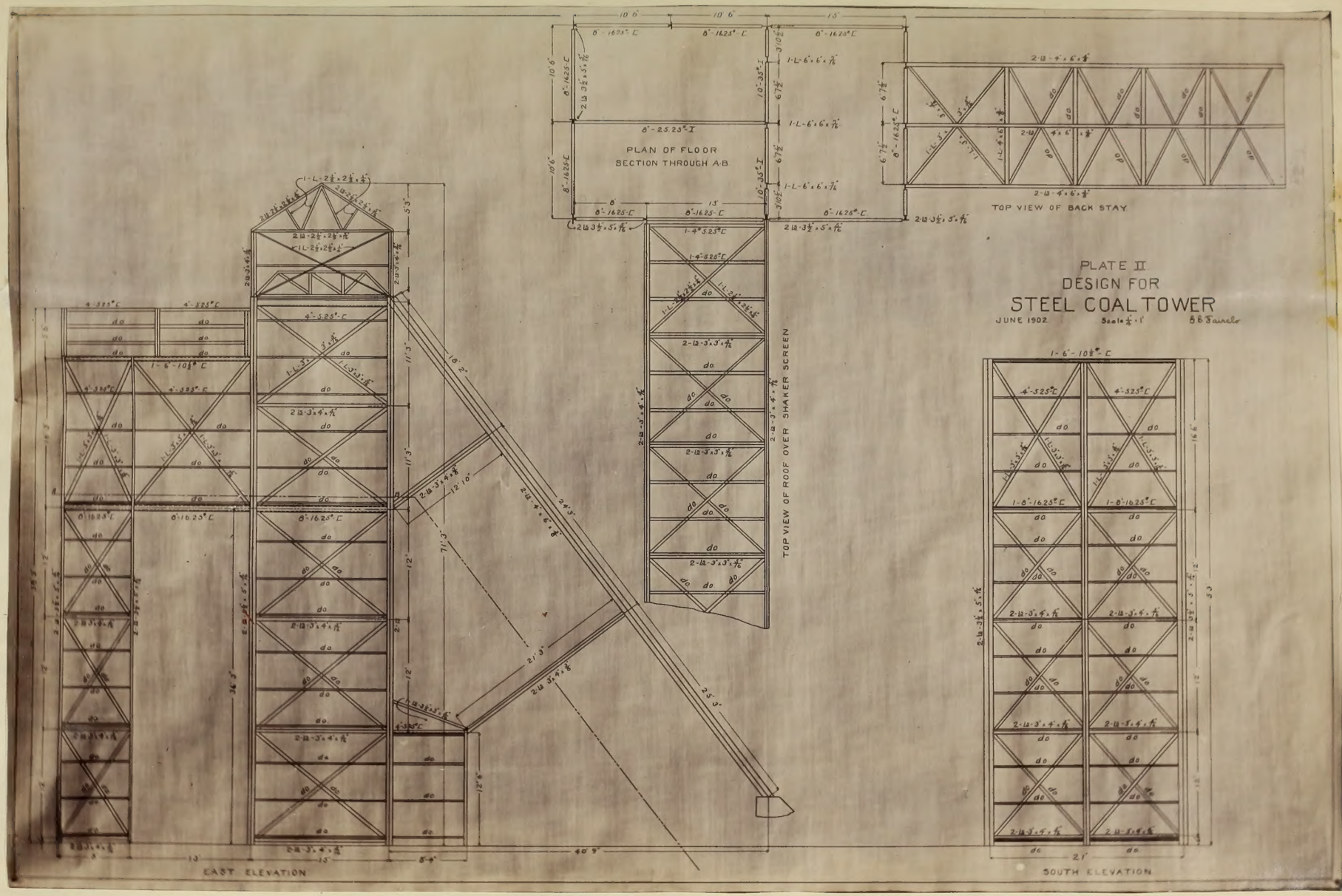


PLATE II

DESIGN FOR

STEEL COAL TOWER

JUNE 1902 Scale $\frac{1}{4}$" = 1' B.B. Farnell

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